APPENDIX 8-B. MAINTENANCE & REPAIR COST DETERMINATION

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APPENDIX 8-B. MAINTENANCE & REPAIR COST DETERMINATION

8-B.1 INTRODUCTION

The maintenance cost is the price of regular scheduled product maintenance ($/year). The repair cost is the price to repair the product when it fails ($). These costs cover all labor and material costs associated with the maintenance or repair of existing products. The determination of the repair cost involves determining the cost and the service life of the components that are likely to fail and includes the labor and the materials associated with the replacement.

Many maintenance and repair costs are estimated using cost tables similar to the ones used in RS Means.[1, 2] Figure 8-B.1.1 shows the methodology for calculating maintenance and repair costs and Table 8-B.1.1 offers an example maintenance/repair cost calculation. All labor costs are derived using the latest 2008 RS Means labor cost by crew type.[2] All repair and maintenance cost tables include a trip charge which is often charged by contractors and calculated to be equal to one half hour of labor per crew member.[2] Labor hours (or person-hours) are based on RS Means data, expert data, or engineering judgment. 2008 Bare Costs are all the costs without any markups. Material costs are based on RS Means data, expert data, or internet sources. The total includes overhead and profit (O&P), which is calculated using labor and material markups from RS Means.[1, 2]

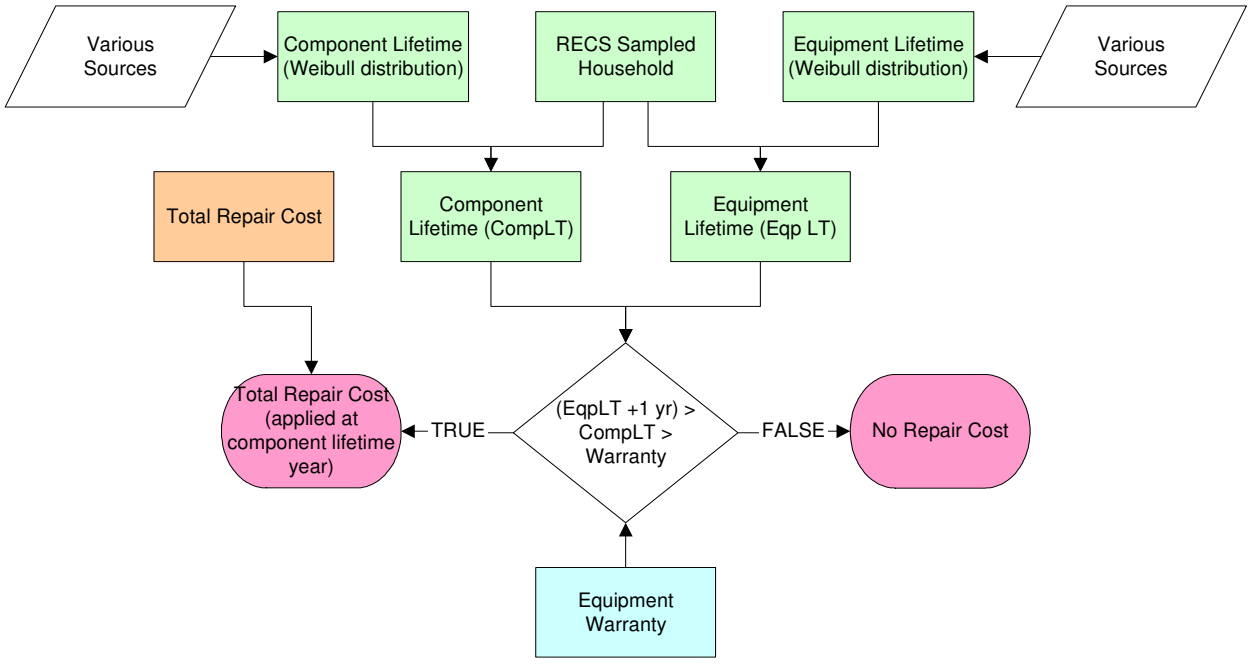

Figure 8-B.1.1 Methodology for Calculating Maintenance and Repair Costs

Table 8-B.1.1 Example Maintenance/Repair Cost Table

Description	Crew	Person-Hours	2008 Bare Costs *(2007$)*				Total incl. O&P
			Mat.	Labor	Equip.	Total	
Trip Charge	CREW1	0.5	$0	$23	$0	$23	$35
Description of Maintenance or Repair	CREW1	0.5	$0	$23	$0	$23	$35
	Totals	1.0	$0	$47	$0	$47	$70

The determination of the repair cost also involves determining the service life of the components that are likely to fail and comparing it to the lifetime of the equipment. Figure 8-B.1.2 shows the methodology for determining repair cost for an individual sampled household. Both component and equipment lifetime are given by Wiebull distributions. During the lifetime of the equipment only a fraction of the sampled households will see a repair cost. Repair lifetime distribution derivations are explained in section 8-B.3.2.

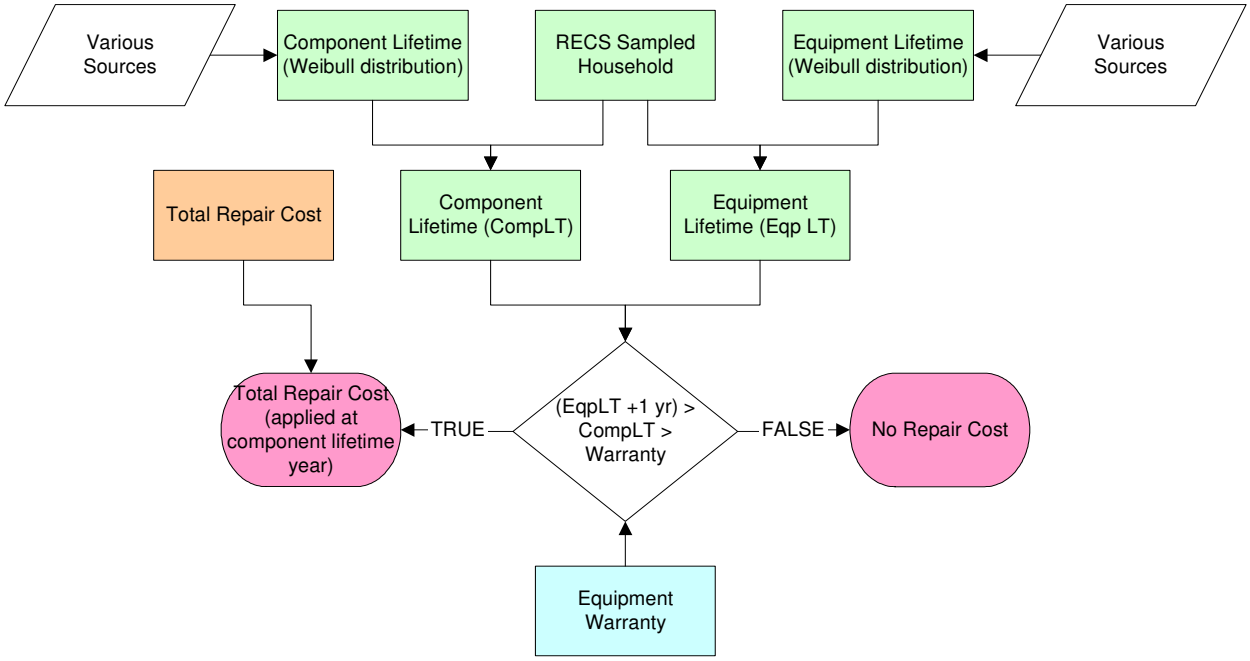

Figure 8-B.1.2 Methodology for Determining Repair Cost for a Sampled Household

8-B.2 MAINTENANCE COSTS

DOE did not include any maintenance cost for residential electric and gas-fired storage water heaters. It did include maintenance costs for heat pump water heaters, oil-fired water heaters, gas-fired instantaneous water heaters, pool heaters, and DHE.

8-B.2.1 Electric Storage Water Heaters

DOE determined that there is virtually no maintenance of electric resistance water heaters. For a heat pump water heater, maintenance includes annual cleaning of the air filter and

a preventative maintenance cost to check the evaporator and refrigeration system. The literature recommends that no professional help is needed for this maintenance.[3, 4] DOE believes there are instances in which such help is needed; thus, for certain heat pump water heater installations it added a preventative maintenance cost to check the evaporator and refrigeration system. For locations where the HPWH might be more exposed to the outdoor environment, such as garages and crawlspaces, DOE applied a 5-year preventative maintenance cost based on Australian HPWH outdoor installations.[5, 6] DOE estimated that 27% of these exposed installations would require this maintenance, based on a survey conducted for central air conditioners.[7] For heat pump water heaters that are located indoors or in basements, the maintenance requirements are considered to be the same as other similar indoor appliances such as refrigerators and room heaters, which don't have any additional maintenance costs [8, 9] For this maintenance cost, DOE based the labor hours and costs on RS Means.[1, 2] The average cost of this maintenance is $81. (See Table 8-B.2.1)

Table 8-B.2.1 HPWH Maintenance

Description	Crew	Person-Hours	2008 Bare Costs *(2007$)*				Total incl. O&P
			Mat.	Labor	Equip.	Total	
Trip Charge	1 PLUM*	0.5	$0	$23	$0	$23	$35
Clean evaporator, drain pan, fans, motors, and drain piping	1 PLUM	0.38	$0	$18	$0	$18	$27
During operation of unit, check refrigerant pressure, add refrigerant as necessary	1 PLUM	0.272	$0	$13	$0	$13	$19
	Totals	1.152	$0	$54	$0	$54	$81

* 1 PLUM means a crew of 1 plumber.

8-B.2.2 Oil-Fired Storage Water Heaters

Oil-fired water heaters and burners are cleaned and maintained regularly. Maintenance is most frequently performed under annual maintenance contracts, which typically includes repair of failed components. The maintenance contracts apply to all energy efficiency levels and no separate repair cost was included.

To derive the cost of the maintenance contract for water heaters DOE collected maintenance contract prices gathered from web sites that represent oil-fired product suppliers in the eastern U.S (see Table 8-B.2.2). This cost varies widely, depending on the presence of other oil-fired products in the residence. The maintenance cost of the oil-fired water heater is usually an additional cost added to the total oil-fired equipment contract. Costs may go down if multiple oil-fired appliances in a household are on the same contract. DOE estimated the average cost of the oil-fired water heater maintenance contract by including half of the average cost of the oil equipment contract and the average cost for the water heater contract option. The average cost of maintenance contracts is $152.59 per year.

Table 8-B.2.2 Maintenance Contract Data Table

Company	Location	Description	Cost of Oil Eqp Contract *(2007$)*	Cost of WH Option *(2007$)*
Brennan Oil	RI, MA	Oil Rite Plan	$175.00	$75.00
Noonan Energy	MA	Basic Plan	$109.95	$35.00
Heritage Energy	NY	Traditional Home Oil Plan	$189.95	$119.95
Hi-Ho Petroleum	CT	Main Burner	$185.00	$85.00
Drum Oil & Propane	NY	Oil Heating System - Plan A	$184.95	$94.95
Richard T. Layton Co.	CT	Oil Burner Service Contract	$164.95	--
Stadium Oil Heat	MA	Service Contract	$169.00	$50.00
Williams Service Company	PA	Oil Hot Water Heater Service Plan	--	$91.95
Solliday Oil Company	MD	Certified Comfort Plan #1	$125.00	--
Slomin's	NY, VA	Econo Pak	$99.00	$26.95
Springbrook Ice & Fuel Service	CT		$180.00	--
Warthen Fuel	MD	PLAN B - Standard Maintenance Agreement	$139.50	--
Kero-Del	MD		--	$89.95
		Average	$156.57	$74.31
		Half of Cost of Oil Equipment + WH Option		$152.59

8-B.2.3 Instantaneous Gas-Fired Water Heaters

The analysis assumes that there is an annual maintenance of residential instantaneous water heaters associated mainly with de-liming the heat exchanger.[10] DOE used a uniform distribution of values from $70 to $100 per year for all energy efficiency levels.[10, 11]

8-B.2.4 Gas-Fired Pool Heaters

Most pool owners do not perform any pool heater maintenance except when the heater does not come on. In such situations, the maintenance work includes verifying controls operation, cleaning burners, cleaning heat exchanger, starting the heater, and measuring water temperature rise. In addition, for advanced design pool heaters it also includes measuring combustion differential pressure. DOE used an average maintenance cost of $351 ($491 for advanced designs), and estimated that the maintenance occurs in the fifth year of the pool heater lifetime if the pool heater lifetime is 6 years or longer.[11]

Consultant provided average number of hours for maintenance[12] and 2008 RS Means was used to calculate the labor rates. (See Table 8-B.2.3 and Table 8-B.2.4)

Table 8-B.2.3 Baseline Pool Heater Maintenance

Description	Crew	Person-Hours	Unit	2008 Bare Costs *(2007$)*				Total incl. O&P
				Mat.	Labor	Equip.	Total	
Trip Charge	2 Plum*	1	Ea.	$0	$47	$0	$47	$70
Verifying control operations, clean burners, clean HX, start up heater, check temperature rise	2 Plum	4	Ea.	$0	$187	$0	$187	$281
Total		5	Ea.	$0	$234	$0	$234	$351

* 2 PLUM means a crew of 2 plumbers.

Table 8-B.2.4 Advanced Design Pool Heater Maintenance

Description	Crew	Person-Hours	Unit	2008 Bare Costs *(2007$)*				Total incl. O&P
				Mat.	Labor	Equip.	Total	
Trip Charge	2 Plum	1	Ea.	$0	$47	$0	$47	$70
Verifying control operations, clean burners, clean HX, measure combustion differential pressure, start up heater, check temperature rise	2 Plum	6	Ea.	$0	$280	$0	$280	$421
Total		7	Ea.	$0	$327	$0	$327	$492

8-B.2.5 Direct Heating Equipment

For direct heating equipment, DOE used the maintenance cost data from the 2007 Furnace/Boiler rulemaking.[13] The costs were derived from a 1994 Gas Research Institute (GRI) report based on field survey sponsored by several gas utilities that repair and service furnace and boiler equipment. [14] The survey estimated the average cost per service call as the average total service charge (parts, labor, and other charges). The average total service charge is $214. DOE used a maintenance frequency of once every five years for all DHE product classes. (See Table 8-B.2.5)

Table 8-B.2.5 Data from GRI Report

Description	**Cost** *(1992$)*	**Cost** *(2007$)*
Case 1 (5-years)	$145	$214

8-B.3 REPAIR COSTS

The repair cost reflects the cost to the consumer for a service call when the product fails. In some cases, if the equipment fails residential consumers tend to replace the equipment rather than having them serviced. This is especially true for water heaters. However, there are design options considered for which the components may encounter repair cost during the lifetime of the equipment.

Components most likely to be repaired include ignition system, gas valve, circulating or combustion blower, electronics/controls/switches, vent system components, and heat

exchangers.[9, 11] DOE analyzed the repair costs of ignition systems, circulating blower, and combustion blower, as well as the cost of the compressor and evaporator fan components for the heat pump water heater design option.

RS Means and consultants provided average number of hours for labor and materials costs. RS Means was used to calculate the labor rates.

8-B.3.1 Component Repair Cost Calculations

Table 8-B.3.1 shows the components most likely to be repaired for each product, as well as cost information and source.

Table 8-B.3.1 Summary of Repair Component Cost Data

Component	Products Used	Material Cost Information	
		Cost *(2007$)*	**Source**
Pilot Ignition (Standing Pilot)	Gas Storage and Instantaneous Water Heaters, DHE (All)	$36	Average value from internet survey[15, 16, 17, 18]
Pilot Ignition (Millivolt)	Pool Heaters	$20	Consultant PH Report[12]
Electronic Ignition (IID or Direct Spark)	Gas (Instantaneous) Water Heaters, Pool Heaters, DHE (All)	$42*	Average value from internet survey[19, 20, 21]
Electronic Ignition (Hot Surface Ignition)	Gas (Storage) Water Heaters		
Combustion Fan (Power Vent or Induced Draft)	Gas Storage and Instantaneous Water Heaters, Pool Heaters, DHE (All),	$110*	Average Value from Consultant WH Report[22]
Main Circulating Air Blower Motor	DHE (FWF, FF, RH)		
Heat Pump Compressor Component	Electric Water Heaters	$110	Average value from internet survey**[23, 24, 25]
Heat Pump Evaporator Fan Component	Electric Water Heaters	$18	Average value from internet survey[26]

* For pool heaters electronic ignition cost is $50 and combustion fan is $175 from consultant report.[12].
** Prices for Embraco Compressor (model #FF10HBK), which was used in ECR WatterSaver model.

8-B.3.1.1 Pilot Ignition Repair Cost

Table 8-B.3.2 shows the repair cost for pilot light ignition (standing pilot) and Table 8-B.3.3 shows the repair cost for pilot light ignition (millivolt). DOE estimated that the repair cost for the pilot light ignition (standing pilot) equals $162, while the cost for pilot light ignition (millivolt) is $145.

Table 8-B.3.2 Pilot Light Ignition (Standing Pilot) Repair Cost

Description	Crew	Person-Hours	Unit	2008 Bare Costs *(2007$)*				Total incl. O&P
				Mat.	Labor	Equip.	Total	
Trip Charge	1 Plum	0.5	Ea.	$0	$23	$0	$23	$35
Repair Pilot Light Ignition	1 Plum	1.25	Ea.	$36	$58	$0	$94	$127
Totals		1.75	Ea.	$36	$82	$0	$117	$162

Table 8-B.3.3 Pilot Light Ignition (Millivolt) Repair Cost for Pool Heaters

Description	Crew	Person-Hours	Unit	2008 Bare Costs *(2007$)*				Total incl. O&P
				Mat.	Labor	Equip.	Total	
Trip Charge	1 Plum	0.5	Ea.	$0	$23	$0	$23	$35
Repair Pilot Light Ignition	1 Plum	1.25	Ea.	$20	$58	$0	$78	$110
Totals		1.75	Ea.	$20	$82	$0	$102	$145

8-B.3.1.2 Electronic Ignition Repair Cost

Table 8-B.3.4 shows the repair cost for electronic ignition (intermittent ignition, direct spark, and hot surface types) and Table 8-B.3.5 shows the repair cost for electronic ignition for pool heaters. DOE estimated that the repair cost for the electronic ignition equals $204, while the cost for electronic ignition for pool heaters is $213.

Table 8-B.3.4 Electronic Ignition Repair Cost

Description	Crew	Person-Hours	Unit	2008 Bare Costs *(2007$)*				Total incl. O&P
				Mat.	Labor	Equip.	Total	
Trip Charge	1 Plum	0.5	Ea.	$0	$23	$0	$23	$35
Repair Electronic Ignition	1 Plum	1.75	Ea.	$42	$82	$0	$124	$169
Totals		2.25	Ea.	$42	$105	$0	$147	$204

Table 8-B.3.5 Electronic Ignition Repair Cost for Pool Heaters

Description	Crew	Person-Hours	Unit	2008 Bare Costs *(2007$)*				Total incl. O&P
				Mat.	Labor	Equip.	Total	
Trip Charge	1 Plum	0.5	Ea.	$0	$23	$0	$23	$35
Repair Electronic Ignition	1 Plum	1.75	Ea.	$50	$82	$0	$132	$178
Totals		2.25	Ea.	$50	$105	$0	$155	$213

8-B.3.1.3 Combustion and Circulating Fan Repair Cost

Table 8-B.3.6 shows the repair cost for combustion or circulating air fan and Table 8-B.3.7 shows the repair cost for power vent fan. DOE estimated that the repair cost for the combustion or circulating air fan equals $297, while the cost for the power vent fan is $368.

Table 8-B.3.6 Combustion and Circulating Air Fan Repair Cost

Description	Crew	Person-Hours	Unit	2008 Bare Costs *(2007$)*				Total incl. O&P
				Mat.	Labor	Equip.	Total	
Trip Charge	1 Plum	0.5	Ea.	$0	$23	$0	$23	$35
Repair Combustion/Circulating Fan	1 Plum	2	Ea.	$110	$93	$0	$203	$261
Totals		2.5	Ea.	$110	$117	$0	$227	$297

Table 8-B.3.7 Power Vent Fan Repair Cost for Pool Heaters

Description	Crew	Person-Hours	Unit	2008 Bare Costs *(2007$)*				Total incl. O&P
				Mat.	Labor	Equip.	Total	
Trip Charge	1 Plum	0.5	Ea.	$0	$23	$0	$23	$35
Repair Power Vent Fan	1 Plum	2	Ea.	$175	$93	$0	$268	$333
Totals		2.5	Ea.	$175	$117	$0	$292	$368

8-B.3.1.4 Heat Pump Water Heater Repair Cost

The repair cost of the heat pump water heater represents the cost of replacing the compressor and the evaporator fan. Table 8-B.3.8 shows the repair cost for the compressor and Table 8-B.3.9 shows the repair cost for the evaporator fan. The estimated average compressor repair cost is $290 and the estimated average fan repair cost is $126.

Table 8-B.3.8 Heat Pump Compressor Repair Cost for Electric Water Heaters

Description	Crew	Person-Hours	Unit	2008 Bare Costs *(2007$)*				Total incl. O&P
				Mat.	Labor	Equip.	Total	
Trip Charge	1 Plum	0.5	Ea.	$0	$23	$0	$23	$35
Repair Compressor	1 Plum	1	Ea.	$168	$47	$0	$215	$255
Totals		1.5	Ea.	$168	$70	$0	$238	$290

Table 8-B.3.9 Heat Pump Evaporator Fan Cost for Electric Water Heaters

Description	Crew	Person-Hours	Unit	2008 Bare Costs *(2007$)*				Total incl. O&P
				Mat.	Labor	Equip.	Total	
Trip Charge	1 Plum	0.5	Ea.	$0	$23	$0	$23	$35
Repair Evaporator Fan	1 Plum	1	Ea.	$18	$47	$0	$65	$91
Totals		1.5	Ea.	$18	$70	$0	$89	$126

8-B.3.2 Lifetime distributions for repair Costs

DOE determined the lifetime of the different product components from several sources. Table 8-B.3.10 lists the gathered lifetime data and the data sources.

Table 8-B.3.10 Component Lifetime Data Gathered

Component	Mean (Median) Lifetime	Data Source	Reference
Standing Pilot Ignition System (Boiler)	9.1 (8.0)	survey	1994 GRI Report[14]
Standing Pilot Ignition System (Furnace)	8.1 (8.0)	survey	1994 GRI Report
Standing Pilot thermocouple	10.2	survey	1993 TSD[9]
Intermittent Ignition (IID)	14	estimate	1993 TSD
IID Electronic Ignition (Boiler)	10.1 (10.0)	survey	1994 GRI Report
IID Electronic Ignition (Furnace)	8.8 (10.0)	survey	1994 GRI Report
Direct Spark Ignition (Boiler)	13.2 (15.0)	survey	1994 GRI Report
Direct Spark Ignition (Furnace)	10.3 (10.0)	survey	1994 GRI Report
Hot Surface Ignitor (Boiler)	16.1 (20.0)	survey	1994 GRI Report
Hot Surface Ignitor (Furnace)	4.6 (6.0)	survey	1994 GRI Report
Ignition (pool heaters)	5.0	estimate	Consultant[12]
Main Circulating Air Blower Motor (Boiler)	14.2 (10.0)	survey	1994 GRI Report
Main Circulating Air Blower Motor (Furnace)	11.4 (12.0)	survey	1994 GRI Report
Induced Draft – Non-Condensing(Boiler)	16.2 (15.0)	survey	1994 GRI Report
Induced Draft - Condensing(Boiler)	22.6 (15.0)	survey	1994 GRI Report
Induced Draft – Non-Condensing(Furnace)	14.8 (15.0)	survey	1994 GRI Report
Induced Draft - Condensing(Furnace)	13.8 (15.0)	survey	1994 GRI Report
Combustion Fan	11.1	survey	1993 TSD
Electronics/Controls/Switches (Boiler)	10.0 (10.0)	survey	1994 GRI Report
Electronics/Controls/Switches (Furnace)	8.7 (10.0)	survey	1994 GRI Report
Gas Valves (Boiler)	14.9 (15.0)	survey	1994 GRI Report
Gas Valves (Furnace)	14.0 (15.0)	survey	1994 GRI Report
Heat Pump Compressor	19	estimate	Based on average Refrigerator lifetime [27, 28]
Heat Pump Evaporator Fan	19	estimate	

DOE used the lifetimes in Table 8-B.3.11 for each component analyzed.

Table 8-B.3.11 Mean Component Lifetime Used in Analysis

Component	Mean Lifetime *(years)*	Products Used
Pilot Ignition (Standing Pilot)	10	Gas (Storage) Water Heater, Gas (Instantaneous) WH, DHE (All)
Pilot Ignition	5	Pool Heaters
Electronic Ignition (IID or Direct Spark)	10	Gas (Instantaneous) WH, Pool Heater, DHE (All)
Electronic Ignition (Hot Surface Ignition)	15	Gas (Storage) Water Heater
Combustion Fan (Power Vent or Induced Draft)	15	Gas (Storage) Water Heater, Gas (Instantaneous) WH, Pool Heaters, DHE (All)
Main Circulating Air Blower Motor	12	DHE (FWF, FF, RH)
Heat Pump Compressor	19	Electric Water Heaters
Heat Pump Evaporator Fan	19	Electric Water Heaters

Table 8-B.3.12 shows the average, minimum and maximum lifetime, as well as the maximum percentile values used to determine the parameters for Weibull distributions. See Appendix J for more information about the derivation of the Weibull distribution parameters. DOE setup the maximum percentile used in the analysis at 99%.

Table 8-B.3.12 Parameters for Generating Weibull Distributions for different Component Lifetimes

	Expert Opinion Values				Weibull Parameters	
Component Failure Year	**Minimum** *(years)*	**Average** *(years)*	**Maximum** *(years)*	**Maximum percentile** *(%)*	**Alpha (scale)**	**Beta (shape)**
5 Year	0	5	10	99	5.6257	2.6548
10 Year	0	10	20	99	11.2513	2.6548
12 Year	0	12	24	99	13.5016	2.6548
15 Year	0	15	30	99	16.8770	2.6548
19 Year	0	19	38	99	21.3775	2.6548

Figure 8-B.3.1 to Figure 8-B.3.8 show the Weibull distribution as well as the cumulative Weibull distribution for each water heater type.

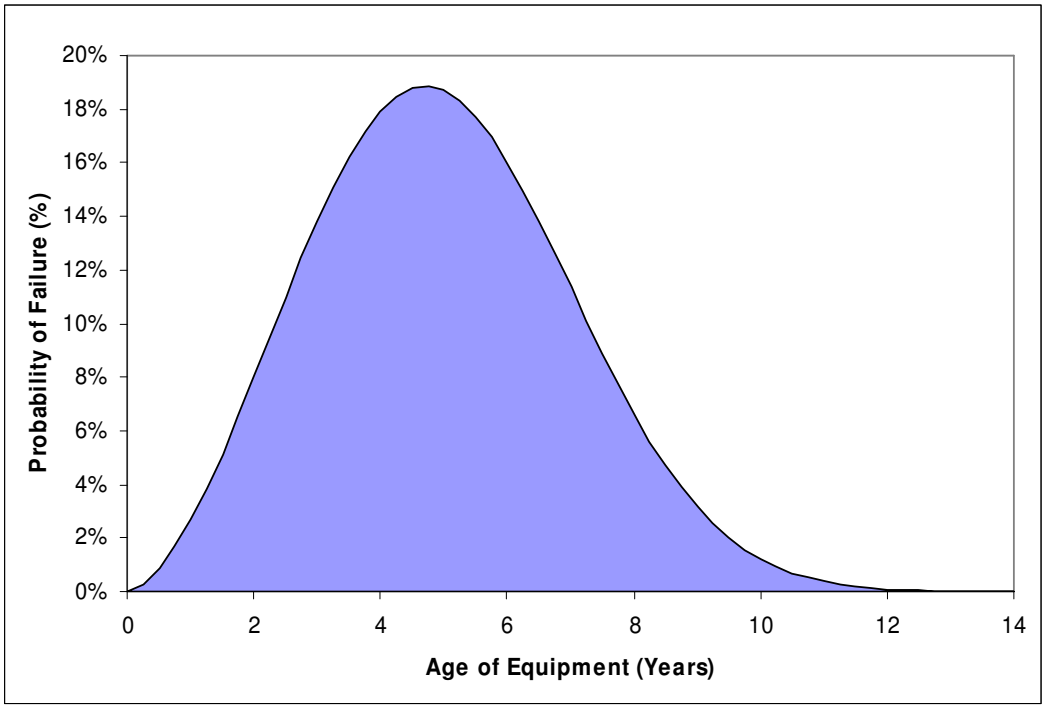

Figure 8-B.3.1 Fraction of the Components with 5-Year Lifetime Failing

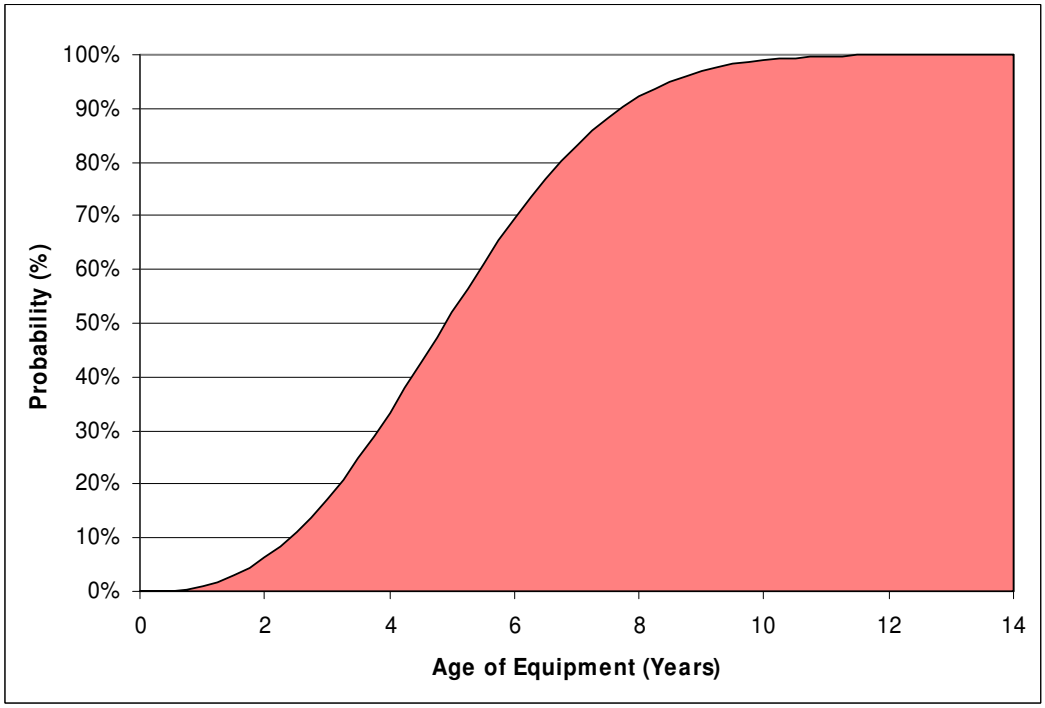

Figure 8-B.3.2 Cumulative Lifetime Length of Components with 5-Year Lifetime

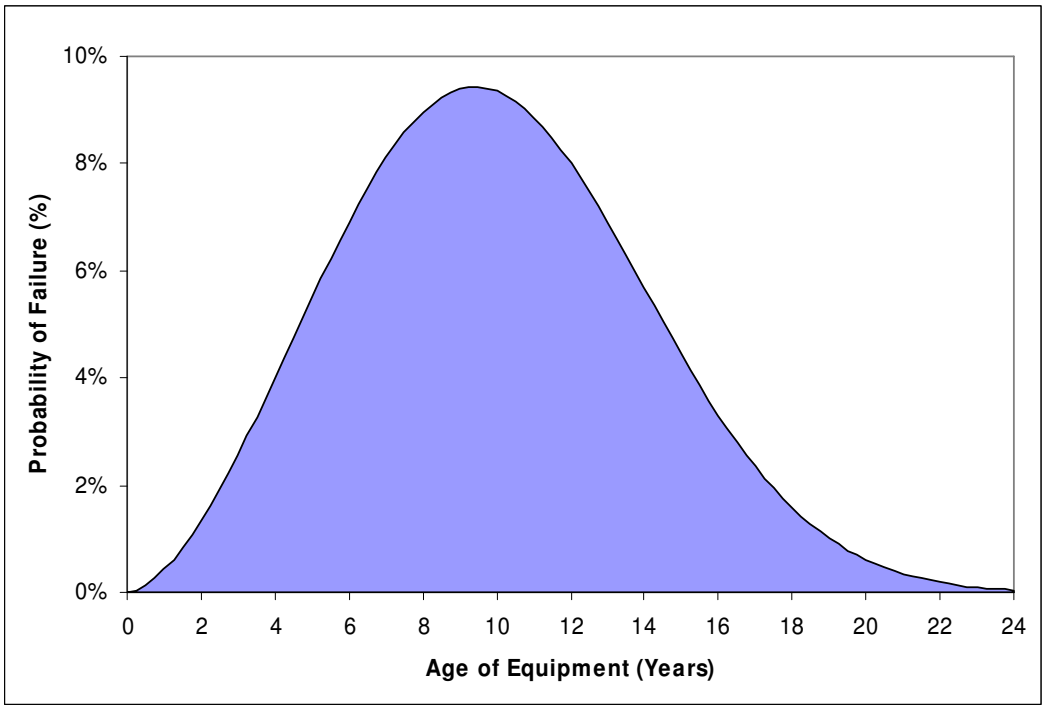

Figure 8-B.3.3 Fraction of the Components with 10-Year Lifetime Failing

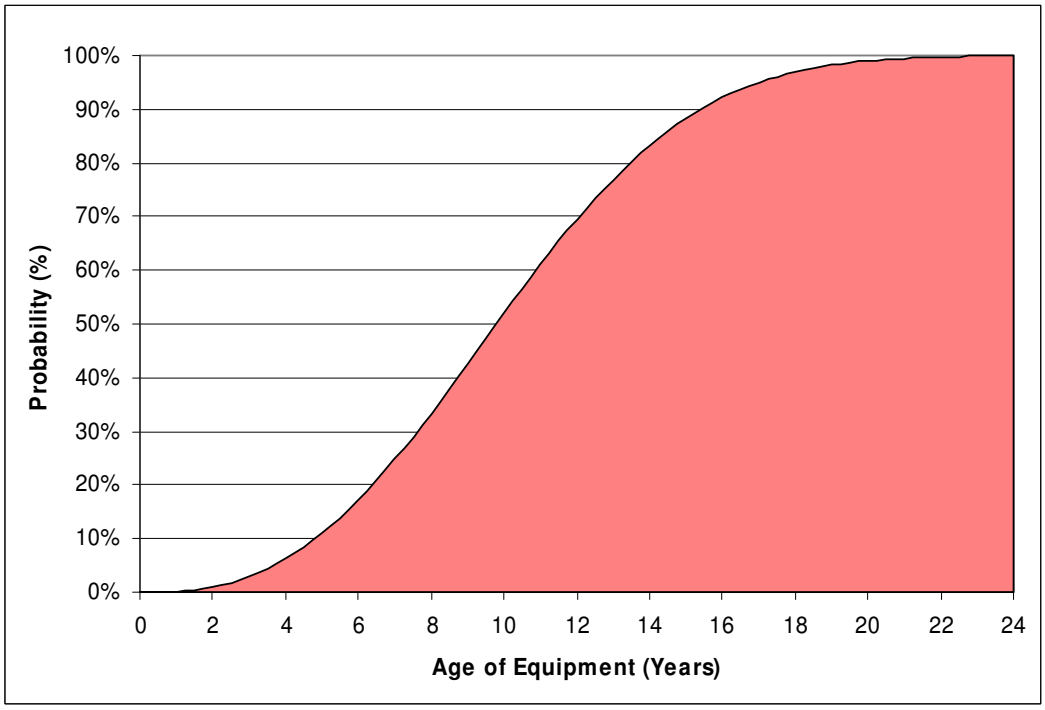

Figure 8-B.3.4 Cumulative Lifetime Length of Components with 10-Year Lifetime

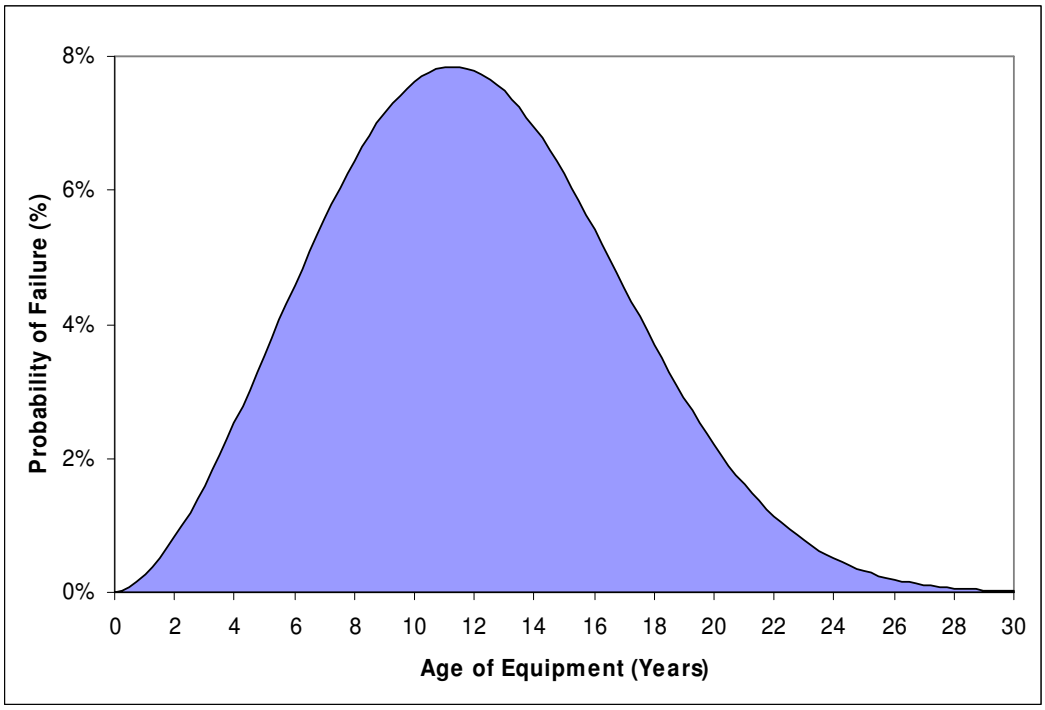

Figure 8-B.3.5 Fraction of the Components with 12-Year Lifetime Failing

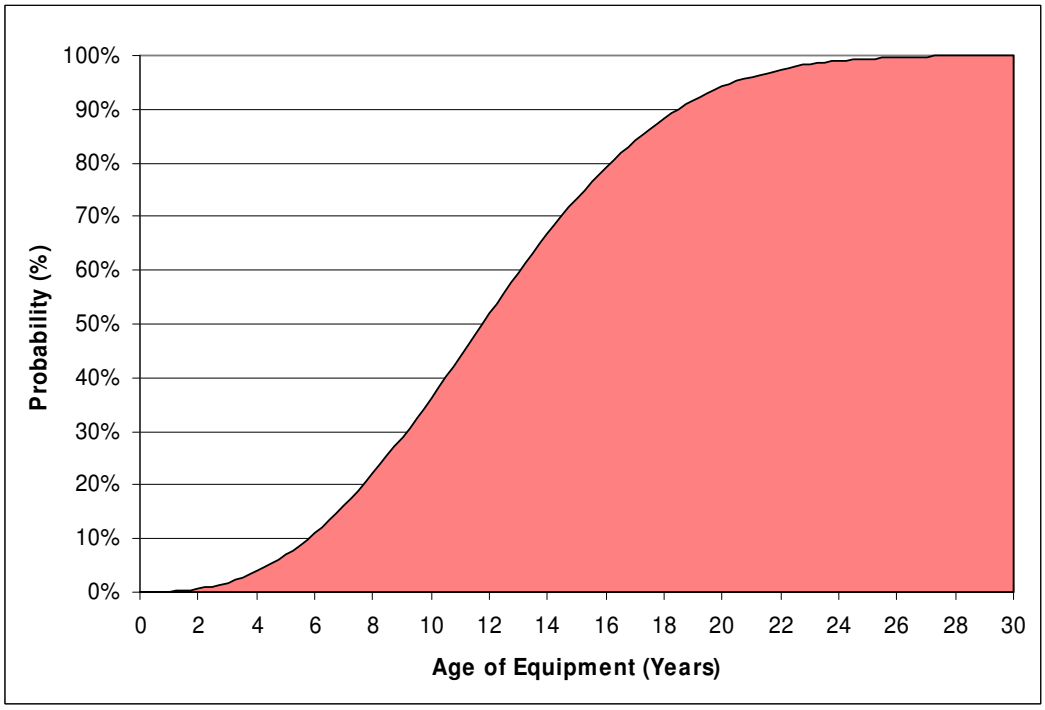

Figure 8-B.3.6 Cumulative Lifetime Length of Components with 12-Year Lifetime

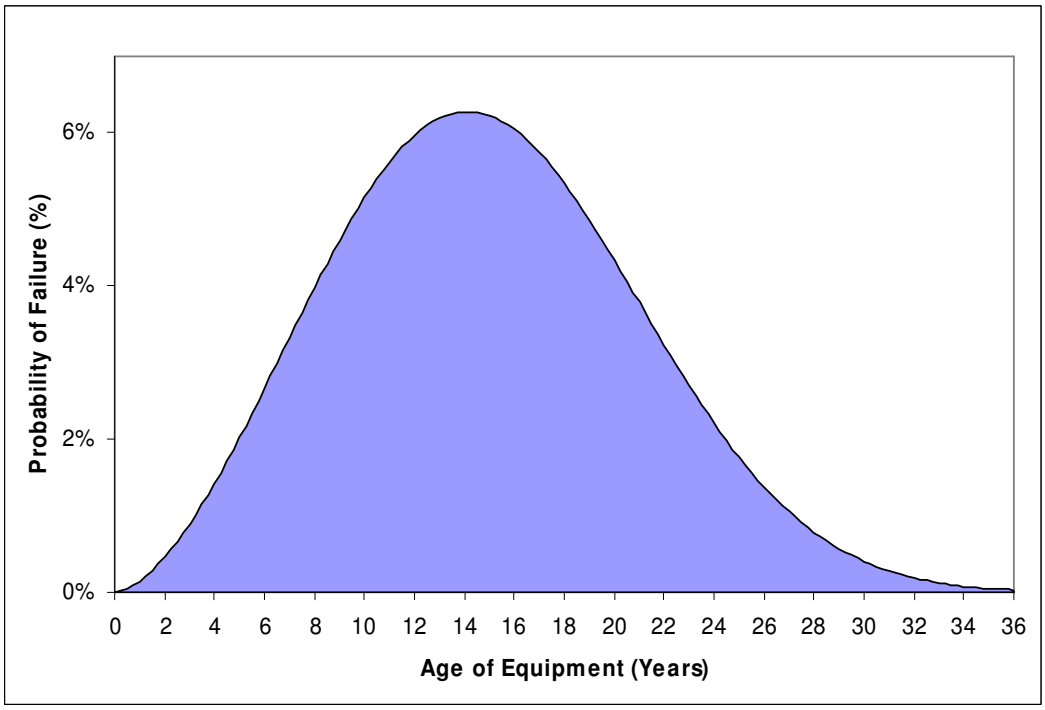

Figure 8-B.3.7 Fraction of the Components with 15-Year Lifetime Failing

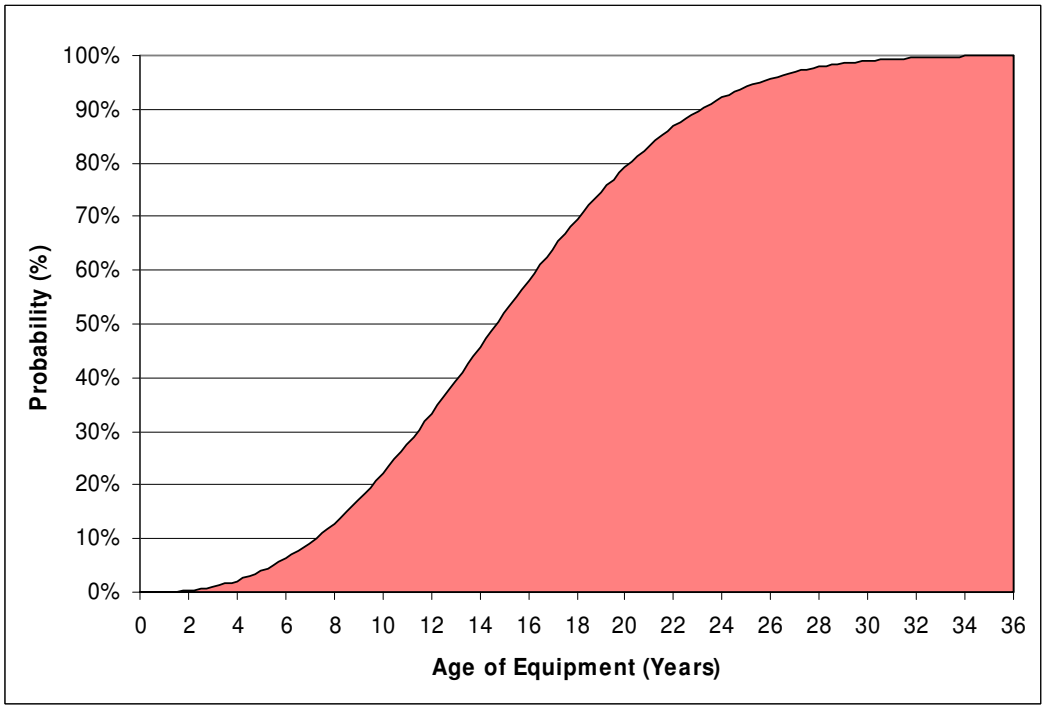

Figure 8-B.3.8 Cumulative Lifetime Length of Components with 15-Year Lifetime

8-B.3.3 Repair Cost Methodology Flowcharts by Product Type

Figure 8-B.3.9 to Figure 8-B.3.13 provide the repair cost methodology flowcharts for each product type.

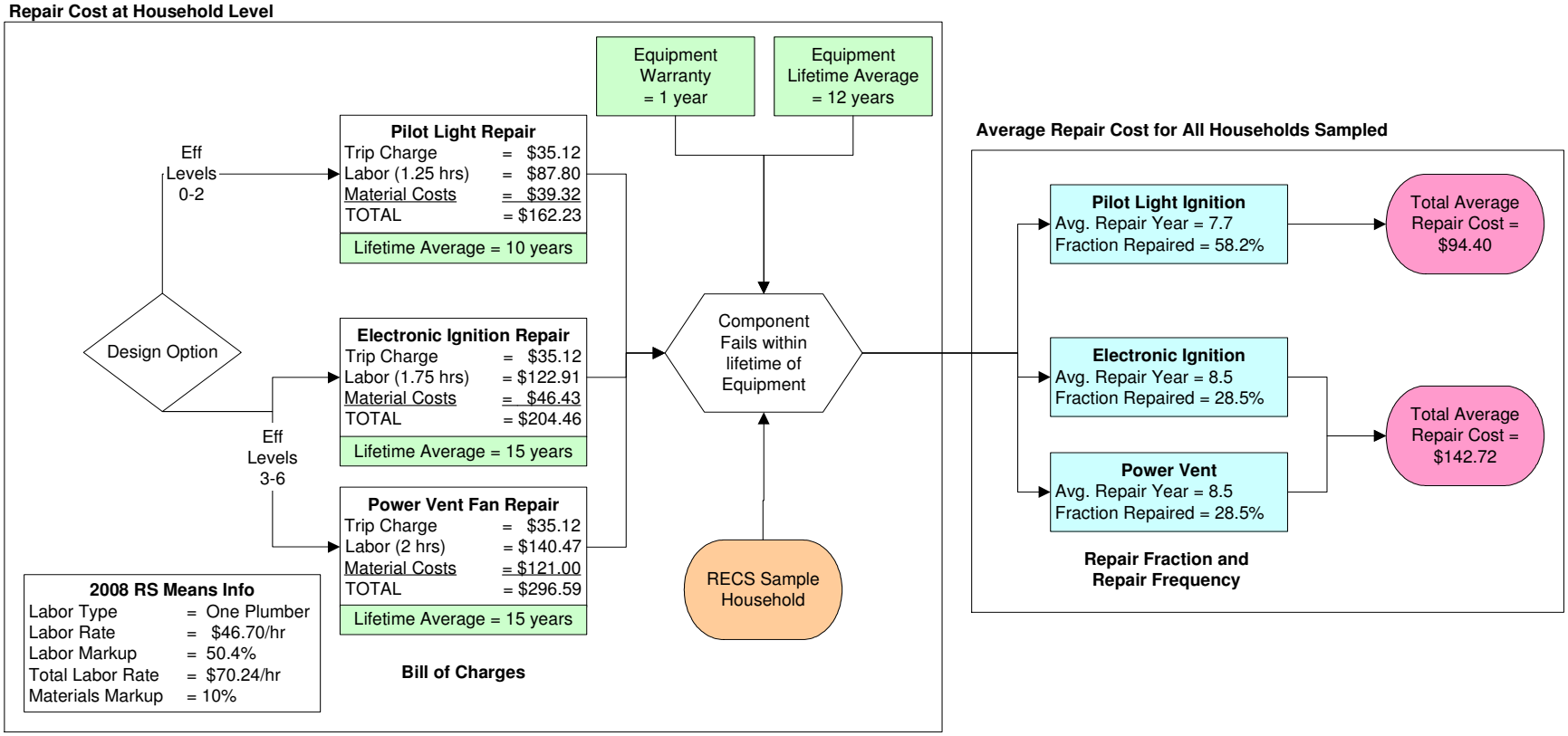

Figure 8-B.3.9 Methodology for Calculating Repair Cost for Gas Storage Water Heaters

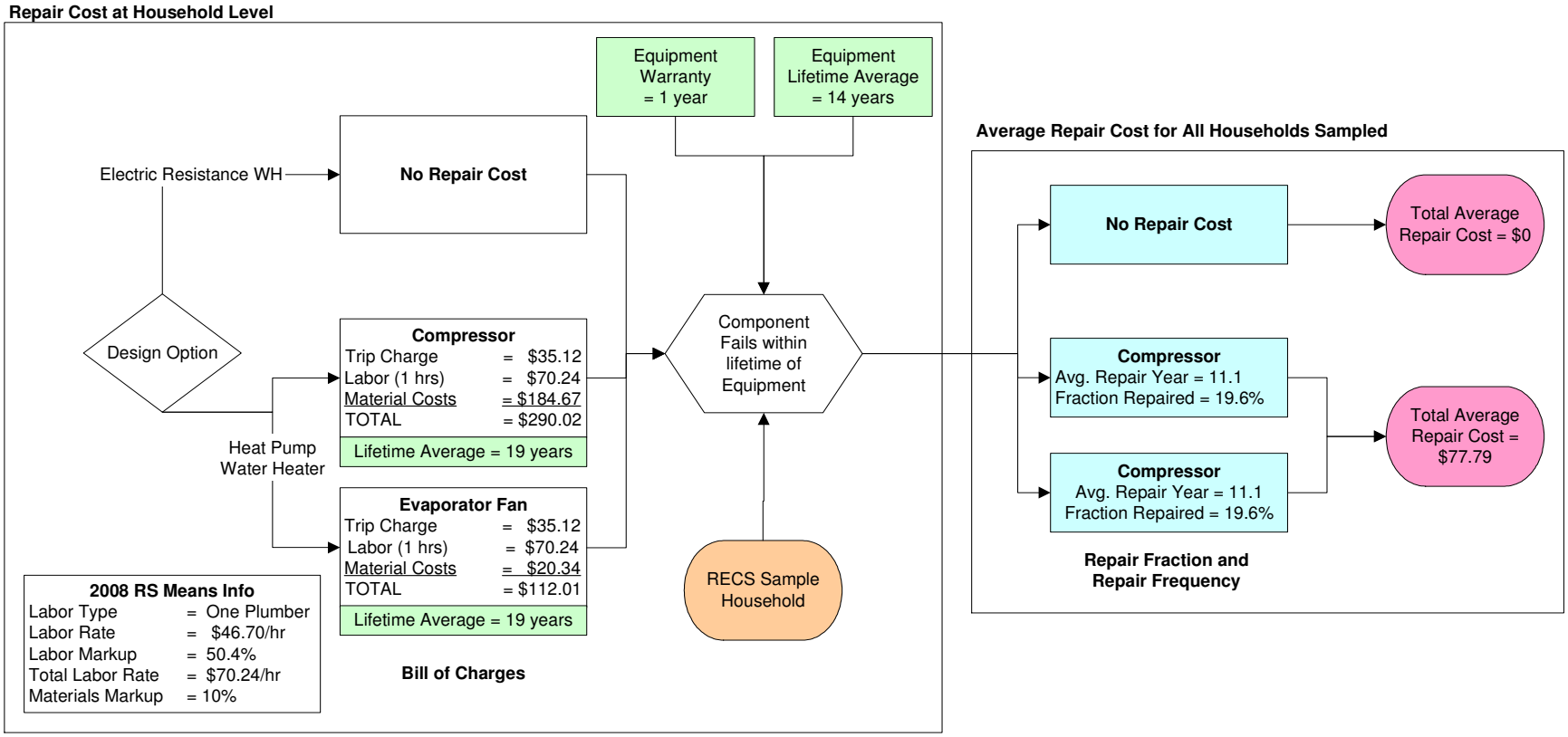

Figure 8-B.3.10 Methodology for Calculating Repair Cost for Electric Storage Water Heaters

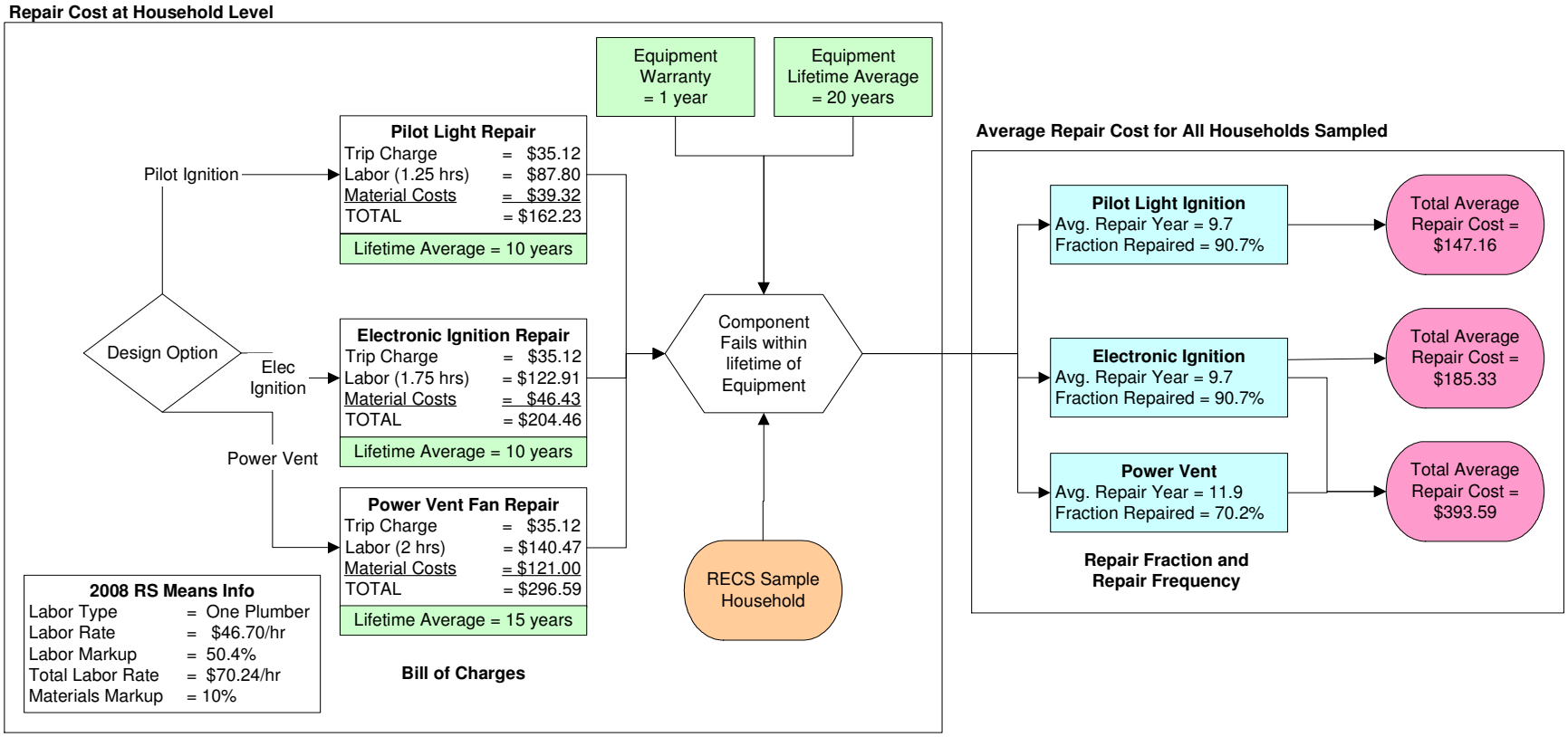

Figure 8-B.3.11 Methodology for Calculating Repair Cost for Gas Instantaneous Water Heaters

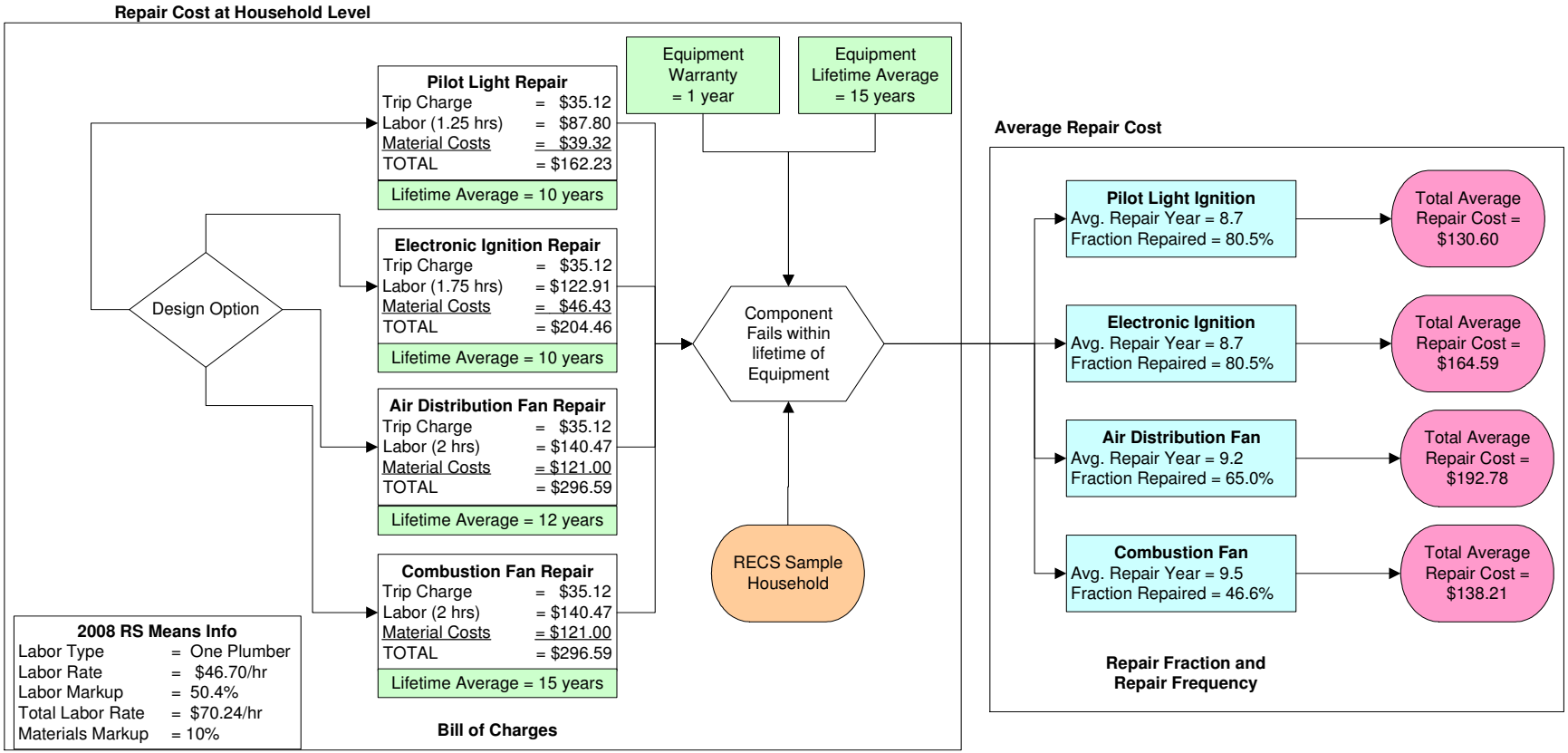

Figure 8-B.3.12 Methodology for Calculating Repair Cost for DHE

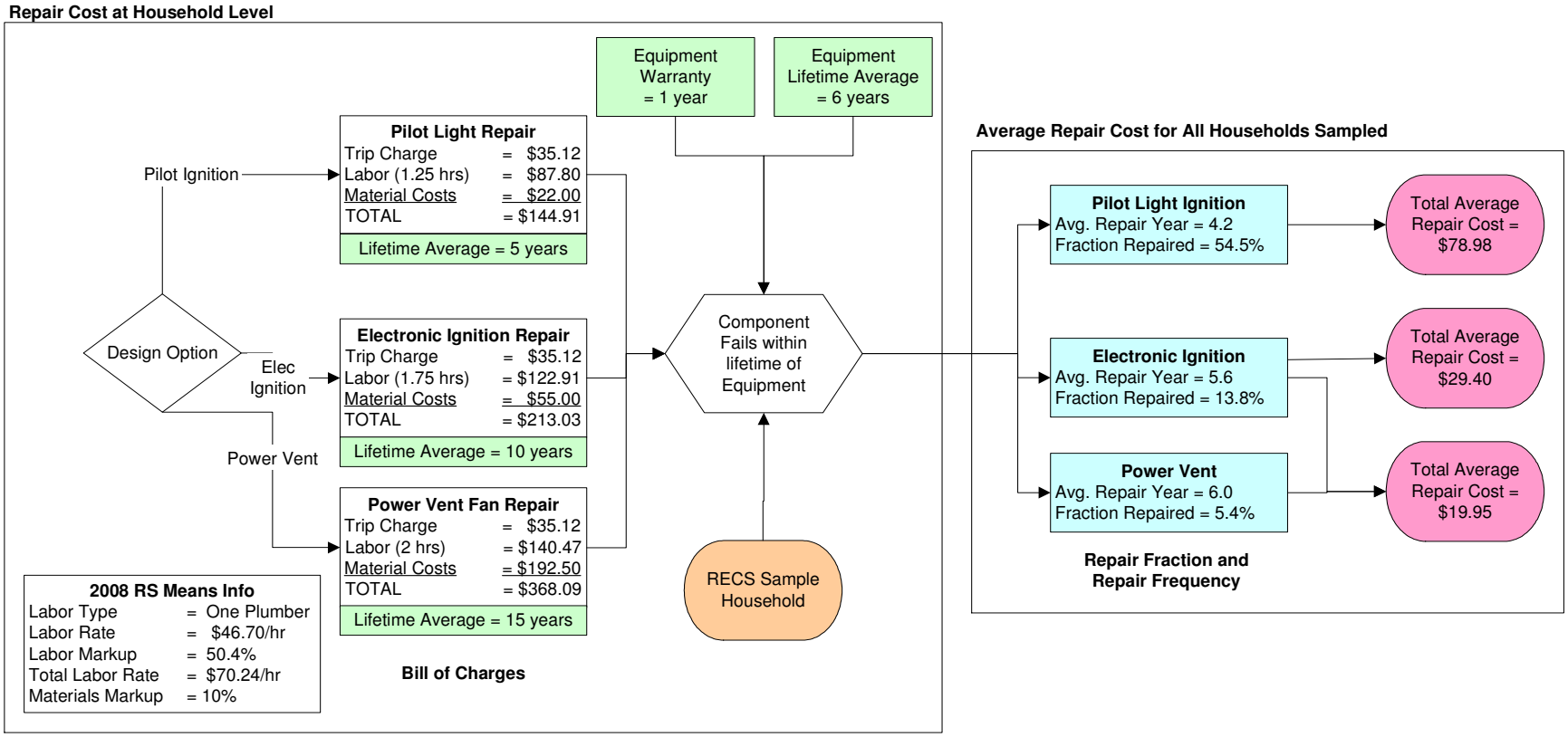

Figure 8-B.3.13 Methodology for Calculating Repair Cost for Pool Heaters

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